Evaluation of Possible Effects of a Tornado on the Integrity of the Record of Decision – Selected Remedy for Operable Unit-1 at the West Lake Landfill

Prepared for

The United States Environmental Protection Agency Region VII

Prepared on behalf of

The West Lake Landfill OU-1 Respondents

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List of Acronyms

ARAR	Applicable or Relevant and Appropriate Requirements
DHS	Department of Homeland Security
EMSI	Engineering Management Support, Inc.
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
MDNR	Missouri Department of Natural Resources
MSW	Municipal Solid Waste
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NSSL	National Severe Storms Laboratory
NWS	National Weather Service
OU	Operable Unit
RIM	Radiologically Impacted Material
ROD	Record of Decision
SFS	Supplemental Feasibility Study
SPC	Storm Prediction Center
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDC	United States Department of Commerce

1. INTRODUCTION

In a July 3, 2013 letter, the Environmental Protection Agency (EPA) requested that the West Lake Landfill Operable Unit-1 (OU-1) Respondents augment the risk analysis section of the Supplemental Feasibility Study [SFS] (EMSI, 2011) to include a discussion about the effects of a tornado on the integrity of the remedial action to be taken at the site (EPA, 2013). EPA indicated that it wanted a qualitative assessment that would also include a discussion of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations associated with a tornado. Engineering Management Support, Inc, (EMSI), on behalf of the OU-1 Respondents, prepared a Work Plan (EMSI, 2013) for this evaluation that was subsequently approved by EPA on July 30, 2013.

The West Lake Landfill is an approximately 200-acre parcel containing multiple landfill units (Figure 1). The site was used for limestone quarrying and crushing operations from 1939 through 1988. Beginning in the early 1950s or perhaps the later 1940s, portions of the quarried areas and adjacent areas were used for landfilling municipal refuse, industrial solid wastes, and construction/demolition debris. In 1973, 8,700 tons of leached barium sulfate residues, (a remnant from the 1940's Manhattan project) were reportedly mixed with approximately 39,000 tons of soil from the 9200 Latty Avenue site in Hazelwood, MO, and transported for disposal to the West Lake Landfill (NRC, 1988). Prior investigations have determined that these radiologically-impacted materials (RIM) were disposed in portions of two separate disposal areas at the site that have subsequently been identified as Radiological Area 1 and Radiological Area 2 or simply Area 1 and Area 2 (Figure 2). Use and placement of the radiologically-impacted soil as daily and intermediate landfill cover material combined with the natural decomposition and consolidation of the refuse has resulted in the RIM now being intermixed with and interspersed within the overall matrix of landfilled refuse, debris and fill materials and unimpacted soil and quarry spoils in Area 1 and Area 2. In some portions of Areas 1 and 2, RIM is present at the surface; however, the majority of the RIM is intermixed with other landfilled waste in the subsurface beneath these two areas.

Landfill activities conducted after 1974 within the quarry areas were subject to permits obtained from the Missouri Department of Natural Resources (MDNR). In 1974 landfilling began in the portion of the site described as the North Quarry Pit (Figure 1). Landfilling continued in this area until 1985 when the landfill underwent expansion to the southwest into the area described as the South Quarry Pit (Herst & Associates, 2005). Together, the North and South Quarry pit landfills make up the permitted Bridgeton Sanitary Landfill while the remaining, earlier landfill areas are part of the West Lake Landfill. In August 2005, the Bridgeton Sanitary Landfill stopped receiving waste pursuant to an agreement with the City of St. Louis to reduce the potential for birds to interfere with airport operations. The Bridgeton Sanitary Landfill is inactive and closure activities are proceeding under MDNR supervision.

This report provides an evaluation of potential impacts if a tornado were to occur over or near Areas 1 and 2 at the West Lake Landfill. Specifically, the potential impacts from a tornado on the remedy selected by EPA in the Record of Decision (ROD) (EPA, 2008) are evaluated. Section 2 of this report presents an overview of the conditions, processes and impacts associated with tornados. Section 3 summarizes the engineering components of the ROD-selected remedy. Section 4 presents an evaluation of potentially applicable or relevant and appropriate requirements (ARARs) of other environmental regulations relative to a tornado. Section 5 presents an evaluation of potential impacts of a tornado on the effectiveness and performance of the ROD-selected remedy. In accordance with EPA's letter, a qualitative evaluation of the potential impacts of a tornado has been performed based on published literature combined with an understanding of the site conditions, the ROD-selected remedy and basic scientific principals and processes. Section 6 lists the reference documents considered in these evaluations.

2. TORNADOES

The National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) defines a tornado as a violently rotating column of air extending from a cumuliform cloud, such as a thunderstorm, to the ground (USDC-NOAA-NWS, undated-a). The United States experiences more tornadoes by far than any other country (NOAA-NWS, 2011b). In a typical year about 1300 tornadoes will strike the United States (NOAA-NWS, 2011b). The peak of the tornado season is April through June (NOAA-NWS, 2011b). More tornadoes strike the central United States than any other place in the world and thus this area has been nicknamed "tornado alley." (NOAA-NWS, 2011b)

2.1 Appearance and Physical Properties

A tornado is a violently rotating (usually counterclockwise in the northern hemisphere) column of air descending from a thunderstorm and in contact with the ground (NOAA-NWS, 2011b). A tornado appears as a rotating, funnel-shaped cloud that extends from a thunderstorm to the ground with whirling winds that can reach 300 miles per hour (Missouri, undated). The funnel cloud of a tornado consists of moist air (NOAA-NWS, 2011b). As the funnel descends, the water vapor within it condenses into liquid droplets (NOAA-NWS, 2011b). The liquid droplets are identical to cloud droplets yet are not considered part of the cloud since they form within the funnel (NOAA-NWS, 2011b). The descending funnel is made visible because of the water droplets (NOAA-NWS, 2011b). The funnel takes on the color of the cloud droplets, which is white (NOAA-NWS, 2011b). Due to the air movement, dust and debris on the ground will begin rotating, often becoming several feet high and hundreds of yards wide (NOAA-NWS, 2011b). After the funnel touches the ground and becomes a tornado, the color of the funnel will change (NOAA-NWS, 2011b). The color often depends upon the type of dirt and debris it moves over (red dirt produces a red tornado, black dirt a black tornado, etc.) [NOAA-NWS, 2011b].

Tornadoes typically track along the ground for a few miles or less and are less than 100 yards wide although rare more violent tornadoes can remain in contact with the earth for well over 50 miles and exceed one mile in width (The Weather Channel, 2012b). However, 75% of all tornadoes are quite weak storms causing only F0 or F1 damage (see discussion below regarding damage assessment) (McCarthy and Schaefer, 2004).

The Nuclear Regulatory Commission (NRC) evaluated tornado characteristics to determine tornado strike probabilities and maximum wind speeds for use in nuclear power plant design (NRC, 2007). This report includes statistical evaluations of the characteristics of tornadoes including lengths and widths of the tornado paths which were used to calculate the overall area covered by the tornado path and subsequently the estimated strike probabilities based on historical tornado occurrences from 1950 through 2003 based on the storm event data maintained by the National Climatic Data Center. The report also evaluated the maximum intensity (wind speed). The reported average path length for tornadoes that occurred in the Central United States ranged from 1.2 miles for an F0 tornado to 15 miles for an F5 tornado (see discussion below regarding tornado intensity). The reported average path width for tornadoes that occurred in the Central United States ranged from 122 ft for an F0 tornado to 1,615 ft for an F5 tornado (see discussion below regarding tornado intensity). Based on a log-normal probability distribution, the expected values for tornado path lengths ranged from 0.91 to 15.6 miles and the expected path widths ranged from 116.5 to 2,080 feet for an F0 through F5 tornado, respectively.

The average forward speed of tornadoes is 30 mph but may vary from nearly stationary to 70 mph (NOAA-NWS, 2010, NOAA-NWS, undated-a; and Missouri, undated). Other reports (NOAA-NSSL, undated-d) indicate tornado movement ranges from almost stationary to 60 mph but that a typical tornado travels at around 10-20 mph. Tornadoes can last from several seconds to more than an hour but most last less than 10 minutes (Edwards, 2013 and NOAA-NWS, 2011b). The average time that a tornado usually stays on the ground is reported to be about five minutes (NOAA-NSSL, undated-d).

2.2 Tornado Formation and Occurrence

Tornadoes mainly come from two types of thunderstorms: supercell and non-supercell (NOAA-NSSL, undated-b). Tornadoes that come from supercells are the most common, and often the most dangerous (NOAA-NSSL, undated-b). Because tornado occurrence in the St. Louis area is primarily related to supercell thunderstorms, factors related to the formation of these types of tornadoes are the primary focus of the discussions presented below. Non-supercell tornadoes are vertically spinning circulations caused by wind shear from a warm, cold or sea breeze front or a dryline (a boundary separating moist and dry air masses) rather than from organized storm-scale rotation (NOAA-NSSL, undated-b).

Thunderstorms develop in warm, moist air in advance of eastward-moving cold fronts (NOAA-NWS, 2010). These thunderstorms often produce large hail, strong winds, and tornadoes (NOAA-NWS, 2010). Tornadoes in the winter and early spring are often associated with strong, frontal systems that form in the Central States and move east (NOAA-NWS, 2010). During the spring in the Central Plains, thunderstorms frequently develop along a "dryline," which separates very warm, moist air to the east from hot, dry air to the west (NOAA-NWS, 2010). Tornado-producing thunderstorms may form as the dryline moves east during the afternoon hours (NOAA-NWS, 2010).

Exactly how and why tornadoes form is not completely understood (NOAA, 2013, NOAA-NWS,2011b, and NOAA-NSSL, undated-a). The most destructive and deadly tornadoes occur from supercells, which are rotating thunderstorms with a well-defined radar circulation called a mesocyclone (Edwards, 2013). Supercell thunderstorms are a special kind of single cell thunderstorm that can persist for many hours (NWS-Birmingham WFO, 2011). Supercells are highly organized storms characterized by updrafts that can attain speeds over 100 miles per hour, are able to produce extremely large hail and strong and/or violent tornadoes, and contain downdrafts that can produce damaging outflow winds in excess of 100 mph, all of which pose a high threat to life and property (NOAA-NWS-BFO, 2011). Supercells can also produce damaging hail, severe non-tornadic winds, unusually frequent lightning, and flash floods (NOAA-NSSL, undated- a). Mesocyclones are detected by Doppler radar and are defined as a large rotating updraft that occurs inside a supercell, typically between 2–6 miles in diameter (NOAA-NSSL, undated-c; NOAA-NWS, undated; and NOAA-NWS, 2010). Most tornadoes form within this area (the mesocyclone) of strong rotation (NOAA-NWS, undated and NOAA-NWS, 2010). NOAA-NSSL researchers discovered the Tornado Vortex Signature (TVS), a smaller, tighter rotation than the mesocyclone, that appears on Doppler radar several kilometers above the ground before a tornado touches down (NOAA-NSSL, undated-c).

The most ideal conditions for supercells occur when the winds are veering or turning clockwise with height (NOAA-NWS-BFO, 2011). For example, in a veering wind situation the winds may be from the south at the surface and from the west at 15,000 feet (4,500 meters) (NOAA-NWS-BFO, 2011). This change in wind speed and direction produces storm-scale rotation, meaning the entire cloud rotates, which may result in a striated or corkscrew appearance to the storm's updraft (NOAA-NWS-BFO, 2011). The rotation within the thunderstorm gives the supercell its classic "hook" appearance which can be seen on radar (NOAA, 2013).

Tornado formation is believed to be dictated mainly by things which happen on the storm scale, in and around the mesocyclone (NOAA-NSSL, undated-a). Within the storm, a strong vertical wind shear (change in wind direction with height) causes a horizontally rotating cylinder of air (NOAA, 2013). Rising air within the thunderstorm updraft lifts the rotating cylinder within the supercell (NOAA, 2013) and tilts the rotating air from horizontal to vertical (NOAA-NWS, 2010). The rotating cylinder of air narrows, becoming stretched, and spins faster and faster forming a tornado (NOAA, 2013). Recent theories and results from the VORTEX2 research program[1] suggest that once a mesocyclone is underway, tornado development is related to the temperature differences across the edge of downdraft air wrapping around the mesocyclone (NOAA-NSSL, undated-a). However, mathematical modeling studies of tornado formation indicate that it can happen without such temperature patterns; and in fact, very little temperature variation was observed near some of the most destructive tornadoes in history near Oklahoma City, OK on May 3, 1999 (NOAA-NSSL, undated-a).

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[1] Verification of the Origins of Rotation in Tornadoes EXperiment2 (VORTEX2 or V2), is a collaborative nationwide project exploring the origins, structure and evolution of tornadoes. https://secure.nssl.noaa.gov/v2news/2009/04/tornado-experiment-to-begin-in-may/

A tornado will gradually lose intensity (NOAA-NWS, 2011b). The condensation funnel decreases in size, the tornado becomes tilted with height, and it takes on a contorted, rope-like appearance before it completely dissipates (NOAA-NWS, 2011b). The details of how tornadoes dissipate are still being debated by tornado scientists (Edwards, 2013). Tornadoes need a source of instability (heat, moisture, etc.) and a larger-scale property of rotation (*vorticity*) to keep them going (Edwards, 2013). There are a lot of processes around a thunderstorm which can possibly rob the area around a tornado of either instability or vorticity (Edwards, 2013).

There are various reports regarding number of tornadoes that hit the U.S. yearly ranging from 1,300 (Edwards, 2013 and NOAA-NWS, 2011b) to approximately 1,200 (NOAA-NSSL, undated-a; NOAA-NSSL, undated-d and NOAA-NWS, undated) to 1,000 (NOAA-NCDC, 2013, to as few as 800 (NOAA-NWS, 2010). The average number of tornado occurrences in Missouri is reported to be 30 (FEMA, 2007b) to 38 per year (FEMA, 2011) to 45 per year (NOAA-NCDC, 2013). More tornadoes occur in Missouri in May than any other month (NOAA-NCDC, 2013). The average annual number of tornadoes (EF-0 to EF-5; see discussion in the next section relative to intensity) in Missouri per 10,000 square miles is reported to be 6.5 compared to an overall average of 3.5 for the entire United States (NOAA-NCDC, 2013). The average annual number of strong (EF-3 to EF-5; see discussion in next section relative to intensity) tornadoes in Missouri is reported to be 2.2 compared to an average annual total of 37.5 for the entire United States (NOAA-NCDC, 2013). The average annual number of strong tornadoes (EF-3 to EF-5; see discussion in the next section relative to intensity) in Missouri per 10,000 square miles is reported to be 0.3 compared to an overall average of 0.1 for the entire United States (NOAA-NCDC, 2013).

2.3 Tornado Intensity or Severity

The severity of tornadoes (e.g., wind speeds) has been primarily characterized based on after-the-fact assessments of the damage caused by a tornado. For almost forty years, the severity of a tornado was described based on the Fujita Scale (F-Scale) devised by Dr. T. Theodore Fujita of the University of Chicago in 1971 (Edwards, et al., 2013, Edwards, et al., undated, NOAA-NWS, 2011b; NOAA-NWS-SPC, 2011; NOAA-NWS, 2003; and Missouri, undated). Scientists rated tornado wind speed on the Fujita F0 – F5 scale based on the damage caused by the tornado (Edwards, et al., 2013, Edwards, et al., undated, NOAA-NWS-SPC, 2011; NOAA-NWS, 2003; Missouri, undated; and NOAA-NWS, 2003). In 2007, the NWS replaced the original Fujita scale with the Enhanced Fujita Scale (EF-Scale) [Texas Tech University, 2004] in all tornado damage surveys in the United States (Edwards, et al., 2013; Edwards, et al., undated; NOAA, 2006; NOAA-NWS-SPC, 2011; NOAA-NWS, 2007; and Missouri, undated). NWS uses the EF-Scale to assign a tornado a “rating” based on estimated wind speeds and related damage (NOAA-NWS-SPC, 2011 and NOAA-NWS, 2007). The EF-Scale is presented below.

Enhanced Fujita (EF) Scale

EF Rating	3 Second Wind Gust (mph)
0	65 – 85
1	86 – 110
2	111 – 135
3	136 – 165
4	166 – 200
5	Over 200

EF-Scale estimates are derived from engineering guidelines including 28 damage indicators (DI) with several degrees of damage (DOD) for each (Texas Tech University, 2004 and NOAA-NWS-SPC, 2011). Even though the EF-scale estimates are based on defined guidelines, they are still only judgmental estimates because nobody knows the "true" wind speeds at ground level in most tornadoes, and the amount of wind needed to cause similar-looking damage can vary greatly, even from block to block or building to building (Edwards, 2013).

Tornadoes have also been characterized by the NWS as "Weak", "Strong" or "Violent" based on percentage of occurrences, typical number of deaths resulting from a tornado, duration or lifetime, wind speeds and EF-rating; however, published explanations of these characterizations are inconsistent (compare for example the percentage of occurrences and wind speeds for these descriptions in USDC-NOAA-NWS, undated, to those presented in USDC-NOAA-NWS, 2010).

2.4 Damages Caused by Tornadoes

On a local scale, a tornado is the most destructive of all atmospheric phenomena (USDC-NOAA-NWS, 2009). The damage path of a tornado can be in excess of 1 mile wide and 50 miles long (FEMA, 2011a, NOAA-NWS, 2010 and Missouri, undated). The damage from tornadoes comes from the strong winds they contain (NOAA-NSSL, undated-d). It is generally believed that tornadic wind speeds can be as high as 300 mph in the most violent tornadoes (NOAA-NSSL, undated-d). Wind speeds that high can cause automobiles to become airborne, rip ordinary homes to shreds, and turn broken glass and other debris into lethal missiles (NOAA-NSSL, undated-d). The biggest threat to living creatures (including humans) from tornadoes is from flying debris and from being tossed about in the wind (NOAA-NSSL, undated-d). It used to be believed that the low pressure in a tornado contributed to the damage by making buildings "explode" but this is no longer believed to be true (NOAA-NSSL, undated-d).

The size and/or shape of a tornado are no measure of its strength (NOAA-NWS, 2011b). Occasionally, small tornadoes do major damage and some very large tornadoes, over a quarter-mile wide, have produced only light damage (NOAA-NWS, 2011b).

Tornadoes can have significant impacts on human activities and communities (NOAA, 2013). Reports of the number of people killed by tornadoes annually ranges from 56 (NOAA, 2013) to 60 (Edwards, 2013) to 60 – 65 (NOAA-NWS, undated-a) to 70 (Missouri, undated) to 80

NOAA-NWS, 2010). The spring of 2011 was one of the deadliest and costliest tornado seasons on record. Between April and June 2011 tornadoes killed more than 580 people and caused over $21 billion dollars in economic damages (NOAA, 2013). The high death toll was partly a result of the tornadoes traveling rapidly through heavily populated areas, a lack of adequate storm shelters and individuals who did not quickly seek shelter (NOAA, 2013).

Other than overly general statements regarding potential for loss of life, injuries, and property damage contained in overview reports and websites regarding tornadoes in general, specific details regarding tornado-induced damages are associated with specific events. Various reports indicate that on average, tornadoes kill 60 people per year, most from flying or falling (crushing) debris (Edwards, 2013).

There are various types of evaluations of damages caused by tornadoes including NWS Service Assessments, FEMA Building Performance Assessment Reports, FEMA Mitigation Assessment Reports, State Disaster Relief requests, and insurance company reports. In order to characterize the nature of damages resulting from tornadoes, reports of damages and photographs of damages associated with the following specific events were reviewed:

- May 22, 2011 Joplin Missouri Tornado (FEMA, 2012, NOAA-NWS-2011c and FOXNews, 2012);
- April 22, 2011 St. Louis Metropolitan Area "Good Friday" Tornado Event (NOAA-NWS, 2012, NOAA-NWS, 2011a and Glass, undated);
- Late-April 2011 Tornado Super Outbreak (FEMA, 2012);
- Mississippi Tornado Outbreak, April 23rd-24th, 2010 (FEMA, 2010);
- The Greensburg, Kansas May 4, 2007 Tornado (FEMA, 2007a; McCarthy, Ruthi and Hutton, 2007; and Marshall et al., 2008);
- Record Tornado Outbreaks of May 4-10, 2003 (NOAA-NSW, 2003); and
- May 3, 1999 Midwest Tornadoes (FEMA, 1999)

Only major tornado events were reviewed because damage assessments and photographs are only available for major events.

Review of the damage assessment reports indicates that the focus of these damage assessments is on the number of deaths, the number of injuries, buildings destroyed or damaged and other property damages; evaluation of the effectiveness of prediction and warning systems; and the performance of buildings and infrastructure. All of these assessments are focused on impacts that occurred to above-ground facilities and structures.

Although it is well recognized that tornadoes pick up dirt, dust and debris, no published information was found regarding the depth of soil scour associated with a tornado impact, the volume or mass of dirt, dust, or debris carried by a tornado, or other qualitative or quantitative measures of soil erosion occurring as a direct result of tornado. This is not surprising when considered in light of the much larger consequences associated with loss of life, injuries, property damage and disruption of services, business, and communities.

There have been reports of tornadoes blowing dirt and creating a trench 3 feet deep, but it is very uncommon (NOAA-NSSL, undated-d). Tornadoes have been known to strip asphalt pavement (NOAA-NSSL, undated-d). Asphalt pavement may strip when tornado winds sandblast the edges with gravel and other small detritus, eroding the edges and causing chunks of asphalt to peel loose from the road base (Edwards, 2013).

No published report, technical document or damage assessment for a historic tornado provided any documentation of, or otherwise indicated occurrences of, significant soil erosion by tornadoes. General studies of wind erosion indicate that bare (unvegetated) soils are subject to wind erosion (USDA-NRCS-NSSC, 2004). The shear force of wind detaches particles protruding from the soil surface, and these detached particles then strike other particles on the surface as they bounce along the surface (USDA-NRCS-NSSC, 2004). This process is called saltation and is the most noted transport mechanism for sand-sized particles (USDA-NRCS-NSSC, 2004). Some studies of soil erosion have addressed storm induced erosion (Cox et al., 2011) but such studies primarily focused on the effects of precipitation and stormwater runoff erosion of tilled topsoil from croplands. Other studies (Ritter, 2012) have examined wind erosion of soil but did not focus specifically on tornadoes or high wind events and again were focused on tilled croplands. Some soil surveys (e.g., Wolf, 1994) have identified occurrences of occasional tornadoes and thunderstorms as possible mechanisms but have concluded that they may only cause damage in scattered areas due to their localized extent and short duration.

Although evaluation of damage to irrigation equipment and crops has been considered as a means of evaluating tornado intensity in rural areas (Guyer and Moritz, 2003), no reports of crop damage or soil erosion associated with a tornado were identified. A Maryland Department of Natural Resources-Forest Service Tornado Damage Assessment Report (Gailey, 2002) did evaluate impacts to woodland (forestland and agricultural land) but this evaluation was focused on damage to trees.

No published information regarding the potential impact of a tornado on grass or other vegetative cover were identified in conjunction with the review of published literature for this assessment. Review of published assessments and photographs of impacts associated with other tornadoes, such as the 2011 Joplin Missouri tornado, the April 22, 2011 “Good Friday” tornado in St. Louis, the April 2011 tornadoes in the southeastern U.S., (FEMA, 2012, 2010, 2007a, and 1999; FOXNews, 2012; Glass, undated; McCarthy, Ruthi and Hutton, 2007; Marshall et al., 2008; NOAA-NWS, 2012, 2011a 2011c and 2003; The Weather Channel, 2012d; and UPI, undated) and the St. Charles and Calvert Counties, MD 2003 tornado (Maryland Department of Natural Resources-Forest Service, 2002), also do not show damage or identifiable impacts to grassy areas.

3. ROD-SELECTED REMEDY

EPA selected a containment remedy for OU-1 that would protect human health and the environment by providing source control and institutional controls for the landfilled waste materials. A description of and reasons for selection of this remedy are presented in EPA's ROD for OU-1 (EPA, 2008). The source control and institutional control methods prevent human receptors from contacting the waste material. The source control method mitigates contaminant migration to air and restricts infiltration of precipitation into the landfill, which contributes to protection of groundwater quality.

The components of the ROD-selected remedy include the following:

1. Install landfill cover meeting the Missouri closure and post-closure care requirements for sanitary landfills, including enhancements consistent with the standards for uranium mill tailing sites (i.e., armoring layer and radon barrier);
2. Consolidate radiologically contaminated surface soil from the Buffer Zone/Crossroad Property to the containment area;
3. Apply groundwater monitoring and protection standards consistent with requirements for uranium mill tailing sites and sanitary landfills;
4. Surface water runoff control;
5. Gas monitoring and control including radon and decomposition gas as necessary;
6. Institutional controls to prevent land and resource uses that are inconsistent with a closed sanitary landfill site containing long-lived redionuclides; and
7. Long-term surveillance and maintenance of the remedy.

The description and basis for the selected remedy was documented in the ROD (EPA, 2008).

Performance standards for each of the remedy components are specified in the ROD (EPA, 2008). As a result of subsequent discussions between EPA Region 7 and EPA's Office of Superfund Remediation and Technology Innovation (OSRTI), the following additional performance standards were identified for the ROD-selected remedy:

- The proposed cap should meet UMTRCA guidance for a 1,000-year design period including an additional thickness to prevent radiation emissions.

- Air monitoring stations for radioactive materials should be installed at both on-site and off-site locations.

- Groundwater monitoring should be implemented at the waste management unit boundary and also at off-site locations. The groundwater monitoring program needs to be designed so that it can be determined whether contaminants from the landfill have migrated across the waste management unit boundary in concentrations that exceed drinking water Maximum Contaminant Levels (MCLs). The groundwater monitoring program needs to measure for both contaminants that have historically been detected in concentrations above MCLs (e.g., benzene, chlorobenzene, dissolved lead, total lead, dissolved arsenic, total arsenic, dissolved radium and total radium) and broader indicators of contamination (e.g., redox potential, alkalinity, carbonates, pH and sulfates/sulfides).

- Flood control measures at the site should meet or exceed design standards for a 500-year storm event under the assumption that the existing levee system is breached.

An evaluation of how the ROD-selected remedy addresses these additional performance standards and a refined description and evaluation of the containment remedy selected by EPA and documented in the ROD (EPA, 2008) was presented in the Supplemental Feasibility Study (SFS) (EMSI, 2011).

4. POTENTIAL ARARS RELATIVE TO A TORNADO

CERCLA remedial actions must be analyzed for compliance with applicable or relevant and appropriate requirements (ARARs) of other environmental regulations. ARARs are divided into three categories:

- Chemical-specific ARARs;
- Location-specific ARARs; and
- Action-specific ARARs.

Descriptions of ARARs, the criteria used to identify whether a regulation is potentially applicable or relevant and appropriate, and identification of potential ARARs for OU-1 are provided in the FS report (EMSI, 2006). Additional evaluations of ARARs are provided in the SFS report (EMSI, 2011).

These prior evaluations identified the various potential ARARs including chemical-specific ARARs associated with the chemicals observed to be present at the site, the location-specific ARARs (e.g., requirements associated with the proximity of the site to Lambert-St. Louis International Airport and the Missouri River), and action-specific ARARs associated with the presence of radionuclides and a municipal solid waste (MSW) landfill at the site. No additional potential ARARs associated with the potential occurrence of a tornado in OU-1 Areas 1 and 2 or possible impacts of a tornado on the ROD-selected remedy were identified during this current evaluation. The previously identified ARARs describe the requirements associated with the design and maintenance of a landfill cover including a cover over radionuclide impacted materials, landfill gas management, odor control, and other aspects of the engineering controls for the site.

Although no specific ARAR was identified relative to a potential occurrence of a tornado in Area 1 or 2, potential information and guidance regarding tornado safety was identified and is considered potentially useful for future work at the site. Based on information obtained relative to tornado safety, future Health and Safety Plans for workers involved in remedial actions at the site should address tornado warning, tornado evacuation and tornado safety (i.e., safe rooms or other safe locations) procedures.

5. POTENTIAL IMPACTS OF A TORNADO ON THE ROD-SELECTED REMEDY

Possible impacts to the components of the ROD-selected remedy that could result from occurrence of a tornado within or near Area 1 or 2 include the following:

- Damage to the vegetative cover on the landfill;
- Wind erosion and scour of the soil layer supporting the vegetative cover; and
- Damage to infrastructure.

Each of these potential impacts are discussed below.

5.1 Damage to the Vegetative Cover

No published information regarding the potential impact of a tornado on the vegetative cover of a landfill, or grass or other vegetative cover in general, were found in conjunction with the review of published literature for this assessment. Earlier this year, an EF-3 tornado did impact the Roxana Landfill in Roxana, IL where reportedly winds of 140 mph destroyed a large storage building used to store plastic trash bins and severely damaged a maintenance facility (FOX2now.com, 2013). After destroying the large storage shed, this tornado lofted debris including plastic trash up into the air and carried it hundreds of yards (FOX2now.com, 2013). Despite severe damage to buildings, review of available video and photographs of the Landfill after the tornado hit does not indicate any identifiable damage to the grass and vegetative cover in the area of the landfill or elsewhere in the area where the tornado impacted (see Appendix A). Similarly, although review of damage assessments and photographs of damage created by historic tornadoes did identify substantial damage to trees, photographs of damage did not indicate extensive or even identifiable damage to grass or surficial vegetative cover (FEMA, 2012, 2010, 2007a, and 1999; FOXNews, 2012; Glass, undated; McCarthy, Ruthi and Hutton, 2007; Marshall et al., 2008; NOAA-NWS, 2012, 2011a 2011c and 2003; The Weather Channel, 2012d; and UPI, undated).

Assuming that a tornado could damage or potentially remove portions of the vegetative cover over Area 1 and/or 2, such an impact is not considered to be significant. First, such an occurrence would be easily identifiable through visual inspection of the landfill cover performed in response to the storm event or in conjunction with regular routine inspection of the site. Second, repairs to the vegetative cover in the form of regrading of damaged areas if necessary and reseeding can be easily and readily implemented. Such damage would be no different from damage caused by a large precipitation event (e.g., a thunderstorm), and as such would be something that would be routinely inspected for and addressed as part of ongoing maintenance activities. Regular inspection and repair of any observed damage to the landfill cover, whether from a tornado or other severe or routine storm event, animal burrowing, or any other cause is anticipated to be part of the ongoing operations, maintenance and monitoring activities to be conducted at the site. Costs for routine repair of the landfill cover were included in the cost estimates provided in the FS and SFS reports (EMSI, 2006 and 2011).

Finally, because the vegetative cover is part of a five-foot engineered cover constructed pursuant to the ROD-selected remedy, no RIM would be impacted by a tornado damaging the surface of the engineered landfill cover. Pursuant to the ROD remedy, all RIM will be confined at least five feet below ground surface under two feet of bio-intrusion rock, two feet of low permeability material, and a final one foot of clean soil supporting the surface vegetation.

5.2 Erosion of the Soil Cover

As previously discussed (Section 2.4), no published report, technical document or damage assessment for a historic tornado provided any documentation of or otherwise indicated occurrences of significant soil erosion by tornadoes. One website addressing frequently asked questions about tornadoes did state "There have been reports of tornadoes blowing dirt and creating a trench 3 feet deep, but it is very uncommon." (NOAA-NSSL, undated-d) This information could not be confirmed by any other published report, government guidance document, website, or any other source.

Assuming that a tornado impact on Area 1 and/or 2 does result in erosion of the soil cover, even down to a depth of three feet as suggested by the NOAA-NSSL website (NOAA-NSSL, undated-d), such an impact is not considered to be significant. First, even the most extensive erosion that could possibly be expected to occur would be limited to the upper portion of the landfill cover (e.g., the vegetative layer and possibly portions of the low permeability soil layer). Second, damage to the vegetative cover, vegetative soil layer, or the underlying low permeability soil layer of the landfill cover would be easily identifiable through visual inspection of the landfill surface performed in response to the storm event or in conjunction with regular routine inspection of the site. Third, repairs to the landfill cover in the form of regrading damaged areas, reconstruction of the vegetative layer and if necessary the low permeability soil layer can be easily and readily implemented. Such damage would be no different from damage caused by a large precipitation event (e.g., a thunderstorm) and as such would be something that would be routinely inspected for and addressed as part of ongoing maintenance activities. Regular inspection and repair of any observed damage to the landfill cover, whether from a tornado or other severe or routine storm event, animal burrowing, or any other cause is anticipated to be part of the ongoing operations, maintenance and monitoring activities to be conducted at the site. Costs for routine repair of the landfill cover were included in the cost estimates provided in the FS and SFS reports (EMSI, 2006 and 2011).

5.3 Infrastructure Damage

A tornado impact in or near Area 1 or 2 could potentially damage or destroy infrastructure associated with the OU-1 remedial action including signage, fence fabric, gates, fence posts, air monitoring stations and associated electrical service, and potentially the surface portions of groundwater monitoring wells (locking cover, surface extension of well casing, etc.). These damages are not considered to be significant in that such damages would be readily identified by visual inspection and could easily be repaired or the damaged infrastructure replaced.

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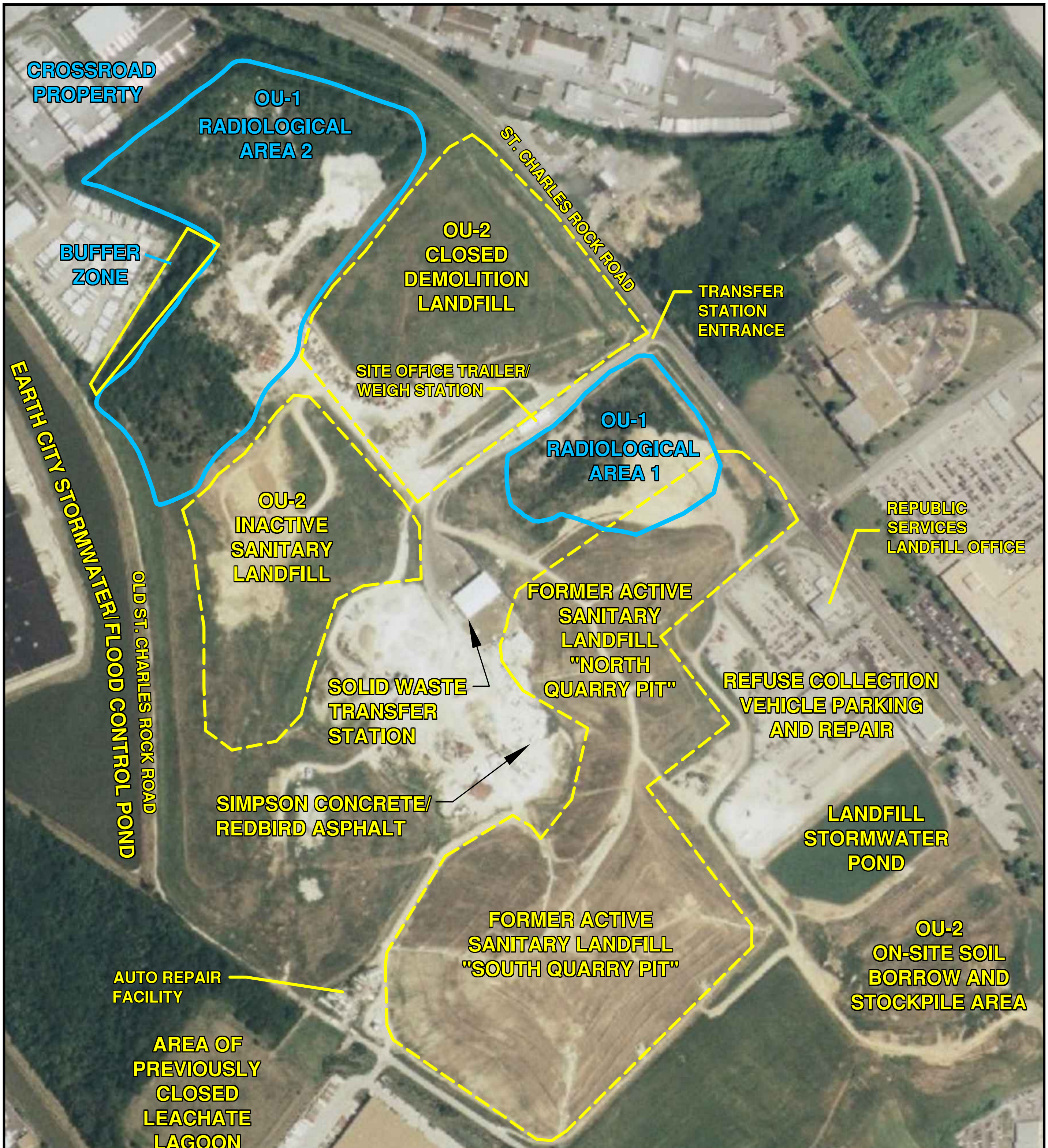
Figures



Source: MyTopo.com Date of Photograph 8/9/2007

N

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SCALE IN FEET

Figure 1

West Lake Landfill Features

West Lake Landfill Operable Unit-1 Tornado Evaluation

EMSI Engineering Management Support, Inc.

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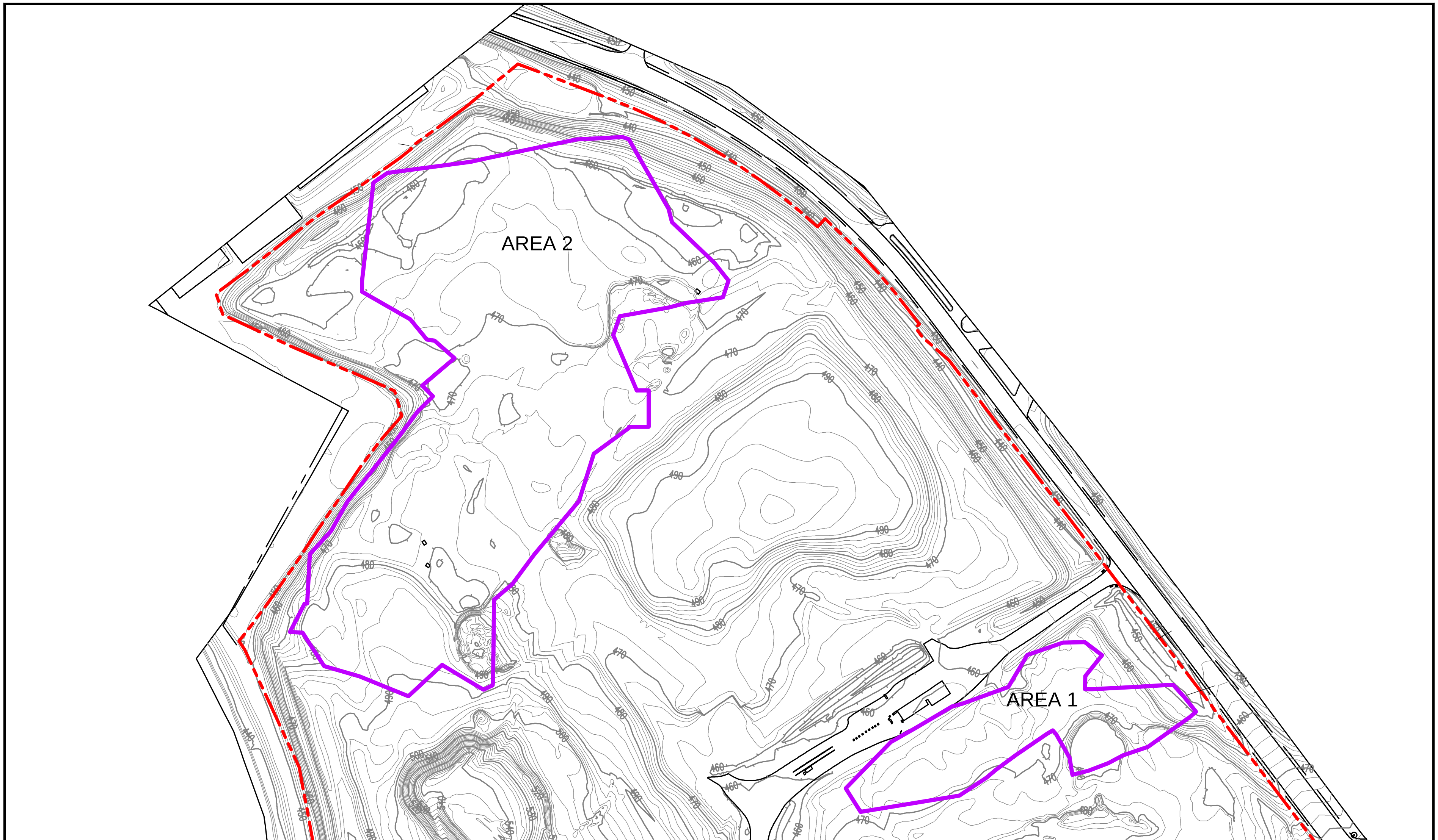

Legend

Estimated Extent of Radiologically Impacted Material

Property Line

Index Contour 10' Interval

Intermediate contour 2' Interval

0 200 400

SCALE IN FEET

Figure 2

Estimated Extent of Radiologically-Empacted Material

West Lake Landfill Operable Unit-1 Tornado Evaluation

EMSI Engineering Management Support, Inc.

Appendix A

Photographs of Tornado Damage at the Roxana Landfill


ROXANA
LANDFILL
4601 CAHOKIA CREEK RD
ROXANA COMPOST SITE
REPUBLIC
SERVICES